

CLAIMS

What is claimed is:

1. A method of electroplating a quaternary alloy comprising nickel and cobalt, comprising:

5 providing an electroplating bath comprising an anode, a cathode, water, ionic nickel, ionic cobalt, at least two ionic alloy metals, and at least one brightener selected from the group consisting of sulfur containing brighteners and organic brighteners; and

10 applying a current to the electroplating bath whereby the quaternary alloy comprising nickel, cobalt, and at least two alloy metals forms on the cathode.

2. The method of claim 1, wherein the at least two ionic alloy metals comprise at least two selected from the group consisting of aluminum, antimony, bismuth, boron, copper, gallium, germanium, gold, indium, iridium, iron, lead, 15 manganese, molybdenum, niobium, osmium, rhodium, ruthenium, scandium, silver, palladium, platinum, tantalum, thallium, tin, titanium, tungsten, vanadium, yttrium, zirconium, and zinc in ionic form.

3. The method of claim 1, wherein the electroplating bath comprises at least one organic brightener selected from the group consisting of acetylenic 20 alcohols, ethylenic alcohols, acetylenic amines, acetylenic esters, acetylenic sulfonic acids and sulfonates, alkoxylated acetylenic alcohols, acetylenic carboxylic acids, coumarins, aldehydes, compounds containing a C≡N linkage, and N-heterocyclics.

4. The method of claim 1, wherein the electroplating bath comprises 25 at least one sulfur containing brightener selected from the group consisting of

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sulfinic acids, sulfonic acids, aromatic sulfonates, aromatic sulfinates, sulfonamides, sulfonimides, sulfimides, and sulfo-betaines.

5 5. The method of claim 1, wherein the electroplating bath has a pH from about 2 to about 6 and a temperature from about 10 °C. to about 90 °C., and a current density of about 1 ASF or more and about 500 ASF or less is applied to the electroplating bath.

10 6. The method of claim 1, wherein the electroplating bath comprises about 10 g/l or more and about 150 g/l or less of ionic nickel, about 0.5 g/l or more and about 70 g/l or less of ionic cobalt, about 0.01 g/l or more and about 20 g/l or less of each of the ionic alloy metals, and from about 0.001 % to about 5 % by weight of at least one brightener.

 7. The method of claim 1, wherein the anode comprises at least one of nickel, cobalt, at least one alloy metal, iridium oxide, platinum, titanium, graphite, carbon, and platinum-titanium.

15 8. The method of claim 1, wherein the quaternary alloy comprises about 2 % by weight or less of components other than nickel, cobalt, and at least two alloy metals.

 9. A method of forming an alloy comprising nickel, cobalt, and at least two alloy metals, comprising:

20 providing an electroplating bath comprising an anode, a cathode, water, about 40 g/l or more and about 100 g/l or less of ionic nickel, about 1 g/l or more and about 30 g/l or less of ionic cobalt, and about 0.05 g/l or more and about 10 g/l or less of each of at least two ionic alloy metals, and from about 0.005 % to about 2.5 % by weight of at least one brightener selected from the

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group consisting of sulfur containing brighteners and organic brighteners; and
applying a current to the electroplating bath whereby the alloy
comprising nickel, cobalt, and at least two alloy metals forms on the cathode.

5 10. The method of claim 9, wherein the electroplating bath has a pH
from about 3 to about 5 and a temperature from about 30 °C. to about 80 °C.,
and a current density of about 10 ASF or more and about 200 ASF or less is
applied to the electroplating bath.

10 11. The method of claim 9, wherein the electroplating bath comprises
at least one sulfur containing brightener selected from the group consisting of
sulfinic acids, sulfonic acids, aromatic sulfonates, aromatic sullfinates,
sulfonamides, sulfonimides, sulfimides, and sulfo-betaines.

15 12. The method of claim 9, wherein the electroplating bath comprises
at least one organic brightener selected from the group consisting of acetylenic
alcohols, ethylenic alcohols, acetylenic amines, acetylenic esters, acetylenic
sulfonic acids and sulfonates, alkoxylated acetylenic alcohols, acetylenic
carboxylic acids, coumarins, aldehydes, compounds containing a C≡N linkage,
and N-heterocyclics.

 13. The method of claim 9, wherein the electroplating bath comprises a
sulfo-betaine brightener.

20 14. The method of claim 9, wherein the electroplating bath comprises
an acetylenic brightener.

 15. The method of claim 9, wherein the electroplating bath comprises
an N-heterocyclic brightener.

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16. The method of claim 9, wherein the at least two ionic alloy metals comprise at least two selected from the group consisting of aluminum, antimony, bismuth, boron, copper, gallium, germanium, gold, indium, iridium, iron, lead, manganese, molybdenum, niobium, osmium, rhodium, ruthenium, scandium, silver, palladium, platinum, tantalum, thallium, tin, titanium, tungsten, vanadium, yttrium, zirconium, and zinc in ionic form.

17. The method of claim 9, wherein the at least two ionic alloy metals comprise iron and boron in ionic form.

18. A method of plating a substrate with an alloy comprising nickel, cobalt, and at least two alloy metals, comprising:

providing an electroplating bath comprising an anode, a cathode substrate, water, ionic nickel, ionic cobalt, at least two ionic alloy metals, and at least two brighteners selected from the group consisting of sulfur containing brighteners and organic brighteners; and

applying a current to the electroplating bath whereby the alloy comprising nickel, cobalt, and at least two alloy metals forms on the cathode substrate.

19. The method of claim 18, wherein the at least two ionic alloy metals comprise at least two selected from the group consisting of aluminum, antimony, bismuth, boron, copper, gallium, germanium, gold, indium, iridium, iron, lead, manganese, molybdenum, niobium, osmium, rhodium, ruthenium, scandium, silver, palladium, platinum, tantalum, thallium, tin, titanium, tungsten, vanadium, yttrium, zirconium, and zinc in ionic form.

20. The method of claim 18, wherein at least one of the two brighteners is selected from the group consisting of acetylenic alcohols, ethylenic alcohols,

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acetylenic amines, acetylenic esters, acetylenic sulfonic acids and sulfonates, alkoxylated acetylenic alcohols, acetylenic carboxylic acids, coumarins, aldehydes, compounds containing a C≡N linkage, and N-heterocyclics.

5 21. The method of claim 18, wherein at least one of the two brighteners is selected from the group consisting of sulfinic acids, sulfonic acids, aromatic sulfonates, aromatic sulfinates, sulfonamides, sulfonimides, sulfimides, and sulfo-betaines.

 22. The method of claim 18, wherein the electroplating bath further comprises at least one conductivity salt.

10 23. The method of claim 22, wherein the conductivity salt is selected from the group consisting of boric acid, sodium sulfate, sodium chloride, potassium sulfate, and potassium chloride.